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CORRELATION OF  
ORDOVICIAN LIMESTONE  
AT SALONA, CLINTON COUNTY,  
PENNSYLVANIA

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By  
LAWRENCE WHITCOMB

Department of Internal Affairs  
Philip H. Dewey, *Secretary*  
Topographic and Geologic Survey  
Geo. H. Ashley, *State Geologist*  
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## FOREWORD

This little paper well illustrates the fine type of geologic work being done in Pennsylvania, without cost to the State, by advanced students of geology as thesis work. Such a study as this in pure science may, at first sight, seem to have little or no practical value. It should be noted, however, that the Trenton limestone here described is one of three relatively thin limestones occurring in the midst of several thousand feet of limestones that have proved over a wide area to be of high quality and are much sought. These three limestones are the Trenton, Lowville, and Stones River. They have been recognized throughout the whole Appalachian region. Because of their wide distribution and their high economic value, geologists the world over will welcome every bit of information dealing with them that will aid in their identification and their mapping in the field.

Furthermore, this study revealed the presence of thin beds of volcanic ash (bentonite) that, in another paper, Mr. Whitecomb has shown gives promise of yielding a more accurate correlation of rock beds at a distance than any other yet found. Further tracing of the bentonite beds may reveal deposits of commercial value. What started out as a labor of love and pure science may some day prove to be the foundation of another industry in Pennsylvania.

*Geo. H. Ashley*

*State Geologist*

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# Plate I

## Legend

- B Bentonite beds 1-5
- Ct *Cryptolithus tessalatus*
- ClS *Climacograptus strictus*
- Da *Diplograptus amplexicaulis*
- Dm *D. Mesogr. mohawkensis*
- HBt *H. Brongniartella trentonensis*
- Ph *Parastrophia hemiplicata*
- T *Triplecia*

## Scale

1 inch = 50 feet

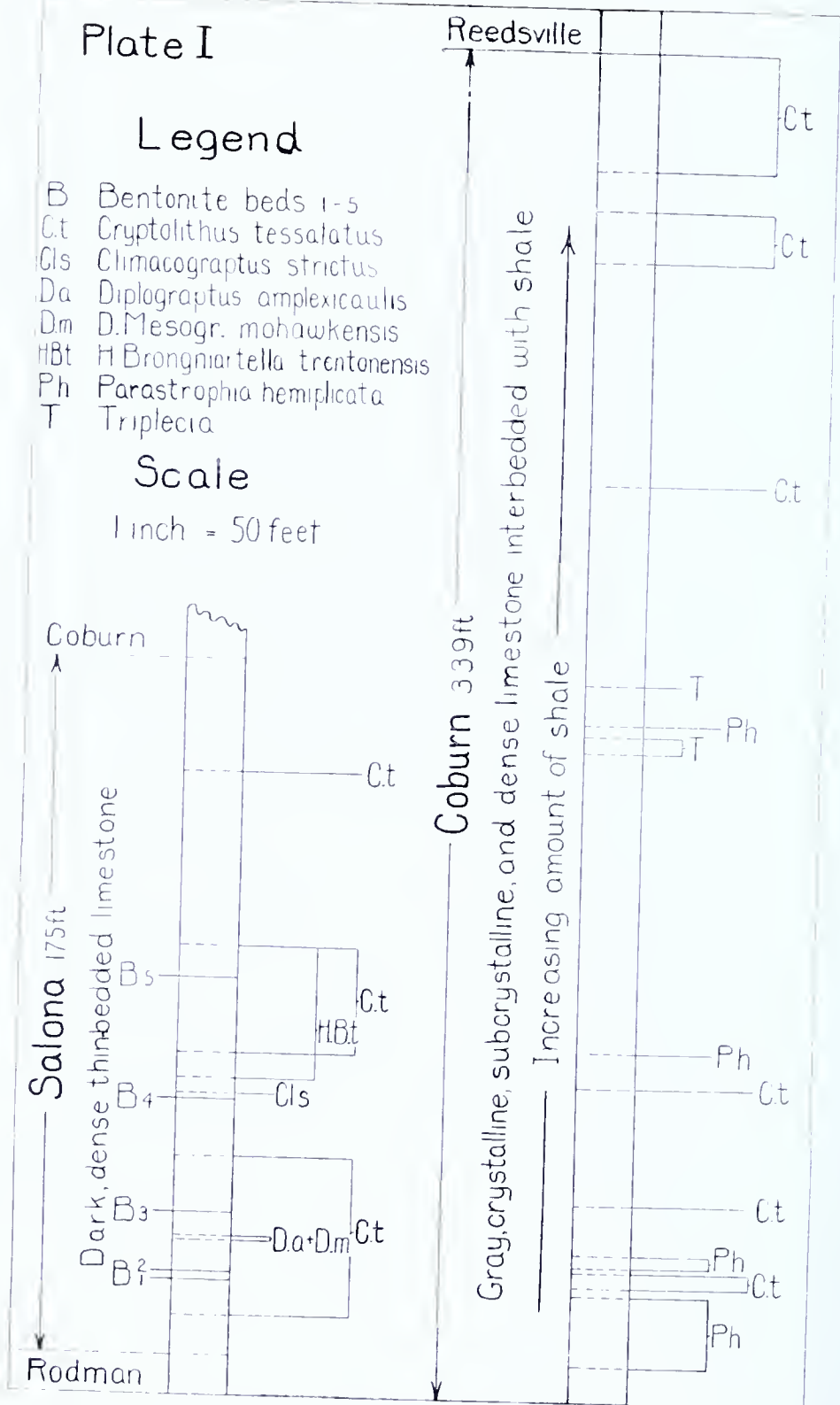


Chart showing thickness of formations, faunal zones, and bentonite horizons at Salona, Clinton County, Pa.

# CORRELATION OF ORDOVICIAN LIMESTONE AT SALONA, CLINTON COUNTY, PENNSYLVANIA

BY LAWRENCE WHITCOMB

## INTRODUCTION

Since the days of the Second Geological Survey of Pennsylvania, the limestones which it called II, the "Valley Limestones," have been the subject of much study. As a result of this work many subdivisions have been made and there are now numerous formations which are recognized and other proposed formations which are not as yet in common usage. In 1919, Professor R. M. Field\* published a paper in which he subdivided the "Trenton" into two separate formations, the Salona, and the Coburn, which terminology is used in this paper.

As a result of study of the Middle Ordovician of central Pennsylvania the writer has obtained some additional information, which seems to substantiate this two-fold subdivision of the "Trenton" for this area. These results are summarized in this paper, which is part of "The Trenton Limestone of Central Pennsylvania," a dissertation presented to the Faculty of Princeton University in candidacy for the degree of Doctor of Philosophy.

The section of the "Trenton" exposed along the railroad track southeast of the Mill Hall gap, near the village of Salona, Lamar Township, Clinton County, Pennsylvania, contains the type section of the Salona formation. It is also the only known section, in central Pennsylvania, where the entire thickness of the "Trenton" is so exposed that it can be studied from bottom to top in one continuous outcrop.

The field work, which extended over a period of thirty weeks in the summers of 1927-28-29, was primarily confined to a study of the lithology of this section and a careful, inch by inch, collection of fossils for the whole 515 stratigraphic feet of the section. In addition to this detailed work, many other sections were studied for additional or confirmatory evidence.

The exposure was developed when the grade for the railroad was blasted from the hillside, along the bank of Fishing Creek. The beds dip from 70° to 80° to the northwest. As the railroad track is roughly perpendicular to the strike of the formation the complete thickness of beds may be studied by working along the track. With the exception of a small thrust fault of five foot displacement, there are no structural complications.

In working up the results of this field work, Mr. B. B. Baneroff, of Blakeney, Gloucestershire, England, who has been doing careful

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\* Field, R. M.: The Middle Ordovician of Central and South Central Pennsylvania; Am. Jour. Sci., 4th Ser., Vol. XLVIII, No. 288, pp. 420, 421, 1919.

zonal work in the Ordovician of Shropshire, has been of great assistance. By constant communication with him, and through the exchange of fossil material, it has been possible to discuss the correlation between the British Ordovician in Shropshire and the Salona formation of central Pennsylvania.

### LITHOLOGY

Although there are many minor changes in the lithology of the section, they may be grouped into three main headings, to wit, the lithology of the Salona, the lithology of the Coburn, and a special grouping to deal with bentonite beds found in the Salona.

The Salona formation is 174 feet thick and is composed of dark argillaceous limestone, which is usually found in thin beds. In most places this limestone is dense, fine grained, and breaks with a slightly conchoidal fracture. At places there are beds which have a more shaly fracture, but they seem to be developed in rock of the same general character. The fossils are distributed throughout this limestone, and it shows no signs of having been reworked since its original deposition.

The Coburn formation is 341 feet thick and has three distinct types of lithology. These types, which are repeated many times, are beds of dense dark gray, unfossiliferous, fine grained limestone; beds of crystalline and sub-crystalline, highly fossiliferous, gray limestone; and beds of calcareous, black shale. The concentration of fossils in the crystalline beds and the rarity of fossils in the fine grained limestone, gives the impression of beds in which all of the fragments on the sea bottom have been concentrated by some physical agent, as bottom "stir-up," wave cutting of low, exposed areas, or current action.

The most striking point in the lithology of the upper part of the section is the way in which the shale beds become thicker and more frequent to the final exclusion of the limestone. At first thin beds of shale, not an inch in thickness, appear between the purer limestone strata. As one progresses up through the section these beds not only become thicker, but they become more frequent. The stage is finally reached where they have become so important that they form one-half of the thickness of the section. They continue to increase until finally one reaches a place where the last bed of limestone is seen, and nothing but shale is to be found above until one is well into the Reedsville shale, which is poorly exposed in this section. There is, therefore, a gradual change from the gray limestones to the shale, with no sharp break at any point in the section. Detailed collecting was stopped at the top of the last bed of limestone, which is taken to be the top of the Coburn.

It was deemed advisable to have chemical analyses made of the rock from different parts of the section in order to see whether there is any variation that would be significant in regard to the conditions of sedimentation. Professor A. H. Phillips, of the Department of Geology, Princeton University, very kindly made these chemical analyses. Three samples were chosen, to give the greatest common variation found in the limestone. Sample 1 was taken from the dense,

black limestone of the Salona formation, sample 2 from the gray, dense, unfossiliferous limestone of the Coburn and sample 3 from a sub-crystalline highly fossiliferous bed in the Coburn. These three types are the main and predominant ones found in the section, and it is believed that the samples are characteristic. The results of the analyses follow:

*Analyses of limestone at Salona*

|                                                                       | 1     | 2     | 3     | Average<br>2 and 3 |
|-----------------------------------------------------------------------|-------|-------|-------|--------------------|
| Al <sub>2</sub> O <sub>3</sub> , Fe <sub>2</sub> O <sub>3</sub> ..... | .50   | .76   | .86   | .81                |
| CaCO <sub>3</sub> .....                                               | 91.71 | 83.16 | 96.23 | 89.69              |
| MgCO <sub>3</sub> .....                                               | .97   | 2.23  | 1.32  | 1.77               |
| Insol. ....                                                           | 6.32  | 13.70 | 1.14  | 7.42               |
| Total .....                                                           | 99.50 | 99.85 | 99.55 | 99.69              |

There are several facts that would seem to be significant from the given results. Upon first inspection one has the impression that there is a great variation between the different samples, and it is only upon second consideration that it is noticed that the analysis of sample 1 is very close to the average between the analyses of samples 2 and 3.

It is now seen that sample 1 and the average of samples 2 and 3 have actually very similar analysis. What may be the cause of this close similarity? Consideration has to be given to the difference in the lithology of the rocks sampled. In the case of 1, which comes from the Salona, the rock has a very uniform lithology throughout a great thickness of beds. Fossils are widely disseminated throughout the entire formation, and there is no appreciable concentration of the fossil contents. On the other hand, in the Coburn, from which the second and third samples were taken, there is a rhythmic variation in the lithology. Certain beds are sub-crystalline and filled with fossils, so much so that they approach shell beds; intermixed with these beds are zones in which fossils are practically nonexistent, the rock being a very fine, dense limestone.

The fact that in the Coburn the fossils are to a great extent concentrated into certain beds, with unfossiliferous beds in between, seems to indicate that this peculiar arrangement had been caused by some mechanical sorting. This might be caused by bottom "stir-up," in which all of the soft unconsolidated material on the bottom was periodically churned up into suspension by wave action. In such a case the heavier shell fragments, first to settle out, form beds chiefly composed of fossils. Following this settling the finer material slowly sinks to the bottom, on top of the shell layer, and gives unfossiliferous beds of dense limestone.

Another possible cause of this banding would be from the reworking of low exposed banks of the sediment, before it has been consolidated. If these beds, with the fossils intermixed with the finer sediment, were raised slightly above the surface of the water, the reworking of the soft material would tend to sort out the shells from the carbonate muds. This sorting action has been recently observed at Andros Island, in the Bahamas, by Professor Field and Mr. Maurice Black.\*

\* Personal communication.

In the cases seen by these observers, the sea was actively cutting into low cliffs, a foot or so in height, washing out the shells, and redepositing them in concentrated beds. These shells did not show the effects of attrition as they were being washed out from a soft, fine, mud and redeposited in soft material. At Andros Island, shells which had been derived by wave cutting from the sediments along the coast were found in the carbonate muds five and ten miles off the coast and were in such a fresh condition that for some time they were mistaken for original benthonic types. It was not until they were ultimately identified as fresh water types, and even pulmonates, that their true significance was recognized.

However if this sorting in the Coburn was caused by the reworking of the unconsolidated sea muds, as exposed in low banks, the beds of concentrated shells should be of limited horizontal extent. There is no known section, in central Pennsylvania, where the Coburn is so exposed that the beds can be traced continuously for any considerable distance, so that it is not possible to say whether these shell bands are lenses, or are persistent over great areas.

It was noticed that practically all of the fossils are part of, rather than whole organisms. Brachiopod remains consist of single valves, trilobite material of isolated cranidia and pygidia, and only in the case of animals which had only one part to the shell, like the gastropods, were complete specimens found. This fact might be considered to indicate reworking of the sediments and the included shells, although it is not by any means conclusive evidence.

If, then, it is considered that samples 2 and 3 are from beds that have been reworked, it is interesting to note how closely the average of their analyses compares with that of sample 1, in which rock there is no evidence of reworking. It would then seem that the general chemical composition holds fairly closely for the limestone of both the Salona and the Coburn.

The conditions of sedimentation may well be considered to have changed from Salona time to Coburn time in such a way that reworking of the sediments was the usual thing in the latter case, and was not present at all in the case of the former, but that the original undisturbed sediments in each case were very similar in all respects.

### Bentonite

The presence of thin beds of bentonite in the Ordovician limestones of the Appalachians, from Alabama to Pennsylvania,\* has been known for some time. Five of these beds were found in the Salona formation and their presence gives rise to some interesting suggestions. In the first place, if the sediments of the Salona had been constantly reworked there would be slight chance of the bentonite beds being preserved. Their absence from the Coburn may be explained either by nonexistence or by the reworking of the sediments which would scatter the bentonite material beyond recognition.

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\* Since this paper was written Mr. G. Marshall Kay has presented a paper at the Toronto meeting of the Geological Society of America, 1930, on the "Hounsfield Metabentonite" of New York, and Mr. D. C. Maddox, Geological Survey of Canada, has published a paper in *Science*, Vol. LXXII, December 19, 1930, on "Bentonite in the Ordovician near Collingswood, Ontario."

The possible origin and stratigraphic use of these bentonite beds is a subject to be discussed in a later paper.\*

### CORRELATION

After a careful analysis of all of the fauna, it was found that the fossils of particular value for correlation purposes, both in this country and abroad, are the graptolites, two trilobites, *Homalonotus* (*Brongniartella*) *trentonensis* and *Cryptolithus tessalatus*, and two brachiopods, *Parastrophia hemiplicata* and *Triplacia* sp. The brachiopods belonging to the genus *Plectambonites* and allied genera might be significant, but the method of fossilization found at Salona made it impossible to study the internal markings of the shells. As their internal structures are of great importance in the classification of this group, nothing could be done with them.

The writer is deeply indebted to Doctor R. Ruedemann, of the New York State Museum, who kindly studied the graptolites and identified them. According to his report, the specimens fall into the following genera and species, *Diplograptus amplexicaulis*, *Diplograptus* (*Mesograptus*) *mohawkensis*, and *Climacograptus strictus*. There were many specimens of *D. amplexicaulis*, but the other two species were represented by single individuals. To quote from Doctor Ruedemann's letter in regard to the specimens of *D. mohawkensis* and *C. strictus*: "Both these species occur here in the lower Canajoharie shale (Trenton age).—The thecae in your specimens are a little closer than in the Canajoharie material.—The Canajoharie shale graptolites are the Trenton graptolites of New York, as our Trenton limestone contains but one graptolite."

All of the specimens of the two species of *Diplograptus* were found in the Salona formation in beds between 29 and 30 feet above the base of the section, while the single specimen of *Climacograptus* was found in a bed between 65.5 and 66 feet above the base of the section. Thus the highest specimen was 109 feet below the top of the Salona.

Of the trilobites, *Homalonotus* (*Brongniartella*) *trentonensis* is one of the most interesting. It is the oldest known Homalonotid in North America, and is closely related to species found in England and Wales. It is confined to the Salona. It is first found 70 feet above the base of the section, and persists for 33 feet, to 103 feet above the base. In these 33 feet it is the most common fossil, and is found in practically every bed which contains any organic remains. It therefore came in and died out suddenly.

*Cryptolithus tessalatus* is not confined to distinct zones as closely as are the other fossils used. Nevertheless it is important as it has two periods of great abundance, one in the lower Salona, and the other in the upper Coburn. In the Salona it was found from 10 to 50 feet above the base and again from 76 feet to 103 feet above the base. These two groups may well be considered as one horizon. There are few isolated occurrences of *Cryptolithus tessalatus* in the next 350 feet, but no horizon where more than one or two individuals were found. However, in the upper 55 feet of the Coburn they are again a very common and characteristic fossil.

\* Whitecomb, L., in press, Jour. of Geol.

It will be noticed that the *Homalonotus (Brongniartella) trentonensis* horizon and the lowest zone of the *Cryptolithus tessalatus* stop at the same point. This is explained by the fact that it is the beginning of the 71 feet of practically infossiliferous limestone, which makes up the top of the Salona. Outside of a few scattered fossils, including some "worm tracks" or "sea weed," this zone is barren. It would therefore seem certain that conditions towards the close of the Salona were such that organisms were unable to live in abundance on or above the bottom. What few fossils are found are probably individuals that were drifted in by currents and could not establish themselves in this unfavorable area. This change in bottom conditions is one of the arguments for the two-fold subdivision of the "Trenton" into the Salona and Coburn.

The brachiopod, *Parastrophia hemiplicata* has a very definite zonal distribution, the first specimens being found 10 feet above the base of the Coburn. They continue for 28 feet. There are occasional, isolated occurrences at higher elevations, but they do not seem to be more than stray individuals of no great significance. *Triplicia* sp. has one of the best defined zones in the section, being confined to four stratigraphic feet, 164 feet above the base of the Coburn.

Observation of these distributions shows that the graptolites and *Homalonotus (Brongniartella) trentonensis* are confined to the Salona, that *Cryptolithus tessalatus* occurs in both the Salona and the Coburn, and that the brachiopods are confined to the Coburn.

On the basis of the graptolites, the Salona would seem to be equivalent to the lower Canajoharie shale or to the Trenton limestone of New York. The trilobite, *Homalonotus (Brongniartella) trentonensis*, is found only in central Pennsylvania, and it is therefore impossible to use it in direct correlation. The absence of this fossil from all other sections might indicate that the beds containing it were laid down at a time which is not represented by fossiliferous sediments in the other "Trenton" sections of eastern North America. As this fossil presumably migrated from the British Isles by the northern route, it should be represented in some of the sections to the north. Its absence from these sections would indicate that the sediments laid down in Salona time had either been eroded, which would give us a particularly significant hiatus, or that the trilobite had arrived by some migratory route which has not been discovered. It is indeed difficult to believe that the beds which contain it can be of the same age as beds to the north which have no trace of the organism. As this fossil occurs below fossils which are found at the base of the type section of the Trenton, at Trenton Falls, New York, it is believed to prove the Salona formation older than the basal Trenton of New York.

The trilobite *Cryptolithus tessalatus* is listed by Bassler<sup>1</sup> as occurring in beds ranging from Trenton to Maysville in age. In the section at Salona they are found in two main zones, near the base of the Salona and again at the top of the Coburn. It would therefore seem that definite correlation cannot be drawn on the sole basis of our present knowledge of the Cryptolithids.

<sup>1</sup> Bassler, R. S., Bibliographic Index of American Ordovician and Silurian Fossils: U. S. Nat. Mus. Bull. 92, Vol. I, pp. 295-296, 1915.

There are two important species of brachiopods to be considered. The first is *Parastrophia hemiplicata* which is largely confined to a definite zone in the section, approximately 30 feet thick, above and near the base of the Coburn. *P. hemiplicata* is known to occur at or near the base of the Trenton in several localities. It was found at the very base at Montmorency Falls, Quebec, by Professor Field,<sup>2</sup> in the summer of 1929.

T. G. White<sup>3</sup> says, "A short distance above the top of the Black River occurs a zone which may be traced the whole length of the lake by its abundance of *Parastrophia hemiplicata*. This fossil occurs scatteringly higher in the series, but nowhere else abundant, and it appears in force without precursors below. The younger specimens very often resemble those of *Triplezia extans*, a fossil which is frequent in a corresponding position above layers containing *Parastrophia hemiplicata* in central New York."

T. H. Clark<sup>4</sup> lists *Parastrophia hemiplicata* as being found five feet from the base, and also at three other zones, to wit, 20 to 30 feet, 270 to 280 feet, and at 400 feet above the base. He also lists it as occurring with three species of *Triplezia*, *T. cuspidata* Hall, *T. extans* Emmons, and *T. schucherti* Clark, in the base of the section. All of these three species are confined to the lowest horizon of *P. hemiplicata*.

In other paper, White<sup>5</sup> lists *P. hemiplicata* as occurring fourteen feet above the base of the Trenton in the Rathbone Brook section.

It would therefore seem that it is common for the Trenton to have a zone of *P. hemiplicata* at or near the base. Various species of *Triplezia* have been recorded from beds of approximately the same age as the beds of the *P. hemiplicata* zone mentioned in the discussion of this species. At Salona *Triplezia* is confined to a four foot zone approximately 125 feet above the *P. hemiplicata* zone.

#### North American Correlations Summarized

Summing up the information given in the preceding paragraphs it is noted that there are many discrepancies between the Salona section and other well known localities, in spite of the fact that it contains a number of fossils common to many Trenton sections. The graptolites seem to give the lower part, or the Salona formation, the faunal aspect of the Canajoharie shale, which is above the basal Trenton. *Cryptolithus tessalatus* is considered to be a typical Trenton to Maysville form, and would seem to make the Salona the equivalent of the Trenton. On the other hand the trilobite *Homalonotus* (*Brongniartella*) *trentonensis*, is not found in any section outside of Pennsylvania, and seems to show that beds of equivalent age are missing in all other sections, or that the known beds were laid down in separate basins or troughs, from which this trilobite was excluded. This then seems to give the Salona an older aspect than basal Trenton.

<sup>2</sup> Personal communication.

<sup>3</sup> White, T. G., Upper Ordovician Faunas in Lake Champlain Valley; Bull. Geol. Soc. America, Vol. 10, p. 459, 1899.

<sup>4</sup> Clark, T. H., A section in the Trenton limestone at Martinsburg, New York; Bull. Mus. Comp. Zool., Vol. LXIII, No. 1, p. 7, 1919.

<sup>5</sup> White, T. G., The faunas of the Upper Ordovician strata at Trenton Falls, Oneida County, New York; Trans. N. Y. Acad. Sci., Vol. XV, p. 94, 1896.

The fact that *P. hemiplicata* occurs so high in the section leads to the supposition that the base of the Coburn is more nearly the equivalent of the base of the typical Trenton section, at Trenton Falls, New York.

The significant point is that *Parastrophia hemiplicata* and *Triplecia*, which are common to the base of the New York Trenton, are entirely absent from the Salona, and occur only in the Coburn.

If the Salona represents sedimentation during a time when there was no sedimentation in New York State, or corresponds to an erosion interval in that area, we might expect to find that certain fossils which occur higher up in the New York sections were living in the Salona seas of Pennsylvania. That they lived thus earlier seems more probable, than that fossil zones which lie at the base of the section in New York should be found well up in the section in Pennsylvania. The presence of *H. (Brongniartella) trentonensis*, of close affinities with British species, is of prime importance, a single new migratory fossil being at times of more significance than several well-known local species.

Therefore, the Salona lies beneath the type Trenton of New York, and above Black River, forming a transitional stage not represented in other localities. The Coburn on the other hand is believed to be the central Pennsylvania formation which is most closely homotaxial with the Trenton of New York; but it is sufficiently different faunally, lithologically and geographically to justify a separate formational name, based upon the principle that formational names should represent time and location.

#### British Correlation

The rocks in Shropshire, England, offer the best chance of intercontinental correlation in the upper Middle Ordovician. This Shropshire section is now being carefully worked, bed by bed, by Mr. B. B. Baneroff, from whom much unpublished information was received. When one studies the fossils from this location, he is impressed by the fact that they are unlike the American species. The brachiopods contain many undescribed genera and species that are not found in this country. Important American species are, on the other hand, absent from the British section. There are at least specific differences in the graptolites, between the two sections. The trilobites of the genus *Cryptolithus* all belong to species other than our American *tessalatus*, and have a distinctive type of brim. The trilobites of the genus *H. (Brongniartella)* are all species differing slightly from the one found in central Pennsylvania. It is here, however, that we get the closest resemblance to an American type.

It would therefore seem that the Caradoc of Shropshire is faunally distinctly different from any section in America with which it might be correlated, unless one considers the Salona formation. The fact that the Salona contains *H. (Brongniartella) trentonensis* which is so closely related to the Shropshire species *H. (Brongniartella) bisulcatus*, would lead to the conclusion that the beds containing these two species might be of approximately the same age. It must be remembered that the rest of the members of the Salona fauna do not check with the British, but rather with the American sections. Although the fauna

of the Salona has many Trenton affinities, it also has some Black River aspects and suggests a transition stage, not found in other sections in America, but which may possibly be correlated with beds in the Shropshire section.

In order to find out what correlations are possible it is necessary to consider the different fossils separately in regard to their British equivalents. According to Doctor Ruedemann,<sup>1</sup> the zone of *D. amplexicaudis* corresponds to the zone of *Dicranograptus clingani* of Great Britain. The second species, *Diplograptus (Mesograptus) mohawkensis*, described by Ruedemann,<sup>2</sup> is said to agree most closely with *D. (Mesograptus) foliaceus*, being only "distinguished by its smaller size, narrower sicular portion and the stronger sigmoidal curvature of the ventral walls of the thecae in the obverse aspect. It does not seem, however, to be nearer related to any of the other British Lower Siluric *Diplograpti*." According to Elles and Wood,<sup>3</sup> *Diplograptus foliaceus* var. *calcaratus* is now listed as *D. (Orthograptus) calcaratus*, which occurs in the zones of *Climacograptus wilsoni*, *Dicranograptus clingani*, and *Pleurograptus linearis*, being most common in the middle zone. The third species *Climacograptus strictus* was described by Ruedemann<sup>4</sup> who says: "This form is possibly identical or vicarious of *C. brevis* Elles and Wood (1906, p. 192), which belongs in the *Dicranograptus* shales, but in some individuals survives into the lower Hartfell shales, or rocks of the age of the Canajoharie shale."

It is therefore seen that the three graptolites found in the Salona formation may all be correlated with the *Dicranograptus clingani* zone of Great Britain. The relationship between this graptolite zone and the zones being established in the shelly facies by B. B. Bancroft is of interest. To quote from one of his letters, "The positions of the graptolite zones in the shelly facies of the Caradoc of this country have never been satisfactorily defined, but it is quite clear that the zone of *Dicranograptus clingani* includes the upper part of my Soudleyan and all of my lower Longvillian. It is also possible that much higher horizons are also included.—As to the utility of the zone of *D. clingani* in the Horderly section, (East Shropshire) I can say that we do not find the fossil, neither does it seem to occur in the correlates of this horizon in the most characteristic shelly deposits of the Welsh area. This seems also to apply to those of its associates which are peculiar to the zone."

The next species to be considered is the trilobite, *Homalonotus (Brongniartella) trentonensis*. In a previous paper,<sup>5</sup> the writer discussed the anatomy of *H. (Brongniartella) trentonensis*, its relationship to *H. (Brongniartella) bisulcatus*, and the question of the correlation of the beds containing fossils of this species with beds in the

<sup>1</sup> Ruedemann, R., Graptolites of New York; N. Y. State Mus., Memoir 11, facing page 6, 1908.

<sup>2</sup> Ruedemann, R., The Lower Siluric Shales of the Mohawk Valley; N. Y. State Mus., Bull. 162, pp. 80-82, fig. 19, 20, pl. 2, fig. 18-19, 1912.

<sup>3</sup> Elles, G. L. and Wood, E. M. R., A monograph of British graptolites; Palaeontographical Soc., pp. 239-241, and 519, 1901-1918.

<sup>4</sup> Ruedemann, R., The Utica and Lorraine formations of New York; N. Y. State Mus., Bull. 262, pt. 2, No. 1, p. 63, 1925.

<sup>5</sup> Whitecomb, L., New information on *Homalonotus trentonensis*; Bull. Geol. Soc. America, Vol. 41, pp. 341-50, 1930.

Shropshire section of England. The conclusion was reached that *H. (Brongniartella) trentonensis* is very closely related to the British species, *H. (Brongniartella) bisulcatus*. It is believed that *H. (Brongniartella) trentonensis* is a migrant from the British stock, and that its slight variation from *H. (Brongniartella) bisulcatus* is the result of this migration and isolation. It has often been pointed out by various geologists that we should expect to find a difference in one or more parts of the anatomy of organisms whose paths of migration led them to such widely separated homes as Wales and Pennsylvania. Therefore the slight difference in the number of annulations in the axial lobe of the pygidium of these two species is not surprising. Otherwise the two species seem to be identical. According to Mr. Bancroft<sup>1</sup> the type specimens of *H. (Brongniartella) bisulcatus* came from the Longville Flags. From unpublished information, kindly supplied by him, it appears that the species *H. (Brongniartella) bisulcatus* is in East Shropshire limited in its stratigraphic range to the Upper Longvillian and Marshbrookian of the Caradoc.

The trilobites of the genus *Cryptolithus* found in the beds of the British and American sections are of different species, and are distinguished by a variation in the brim type. The following extract from one of Mr. Bancroft's letters dealing with specimens of the species *C. tessalatus*, gives his opinion regarding the brim type, and the probable relative ages of the species. "The type of fringe [brim] presented by your specimens has not been found in this country, but the species undoubtedly belongs to the group embracing our *C. gibbifrons* and the allied forms I am now publishing.<sup>2</sup> These British species have two concentric rows of pits external to the girder, whereas yours has but one. The nearest approach to the Trenton type is found in a species from the lower half of the Horderly Sandstone, in which the two rows on the sides are represented by about six large pits in single series in front. I expected that species with a single row external to the girder would occur at a much lower horizon, and am surprised that they should be found associated with Horderly and post-Horderly *Brongniartella*." As *C. tessalatus* has but one row of pits external to the girder it is a more primitive type than the British *Cryptolithids*, in which a second external row has been developed by the splitting up of the original row.

The brachiopod, *Parastrophia hemiplicata*, does not, to the best of the writer's knowledge, occur in the British sections, and is therefore of no use in correlation between these sections. The brachiopod, *Triplecia* sp., from the Coburn, does not seem to be present in the British sections. To quote from another letter from Mr. Bancroft, "I should not care to say that your Trenton form belongs to any British species of *Triplecia*, though it certainly is not unlike a form from the Upper Ordovician of Portrane, Ireland, (Davidson, Sil. Brach., Pl. 37, fig. 9)." Thus it is evident that this brachiopod will not help in the correlation.

The probable correlation of the Salona and Coburn formations is dependent on the foregoing statements. Considering the information that has been given, it is seen that the graptolites do not give much

<sup>1</sup> Personal communication.

<sup>2</sup> Bancroft, B. B., Some new species of *Cryptolithus*, (S. L.) from the Upper Ordovician; Mem. & Proc. Manchester Lit. & Philos. Soc., Vol. 73, pp. 67-98, pl. 5 and 6, May, 1929.

help in this problem. The zone of *Dicranograptus elingani*, with which the Salona specimens are correlated, is of such stratigraphic extent that no fine correlation can be made from it, but it does have a limiting value, which should be useful as a check on the information gained from the other fossils. The brachiopods in the sections on opposite sides of the ocean are not only of different species, but probably of different genera and so are of little use. Of the trilobites we have considered two very interesting genera, *Homalonotus* (*Brongniartella*) and *Cryptolithus*. It has been shown that the American Cryptolithids, which are associated with *H. (Brongniartella) trentonensis*, have a more primitive type of brim than the English species that are found with *H. (Brongniartella) bisulcatus*. The primitive type, from which all of these species were developed, must have been older than the Soudleyan species. It is believed that the ancestors of our *Cryptolithus tessalatus* migrated from the center of Cryptolithid development in pre-Soudleyan time, when the dominant brim type had one exterior row of pits. As there is no evidence that the Trenton *C. tessalatus* ever developed two exterior rows of pits, it should be looked upon as an isolated species, which would not be effected by developments in the parent stock.

It is a common fact that the most primitive types of organisms are often found farthest from the original center of distribution because of their isolation and conservatism. Those which are within the sphere of influence of the great parent stock all tend to change more rapidly, and to conform to a general standard. Thus, the Cryptolithids in North America in Trenton time represent a single migration that started from the center of distribution previous to the development of the two exterior row brim type. There is no fixed rate of migration for trilobites known, and once such organisms left their original habitat, they may have moved rapidly or slowly without great changes in their anatomy. Thus, if the Cryptolithids left the central stock in pre-Soudleyan time, there is no fixed time at which they should have reached America. The American species with the one exterior row brim type may therefore be contemporaneous with the two exterior row British type, which presumably developed at or near the center of distribution. The stratigraphic distribution of *Cryptolithus tessalatus* in the Trenton of North America shows that the species was, in many sections, abundant at more than one time; and the individuals found between these periods of abundance prove that it has not been exterminated. This distribution may be caused by the animal having migrated from one locality to another, as conditions in the sea became less favorable, allowing an occasional individual to stray into areas of sea where it could not survive.

Consideration of the genus *Homalonotus* (*Brongniartella*) shows that it is the most important link between the faunas of the two countries. The stratigraphic value of this trilobite cannot be over-emphasized, as it appears to mark the one and only datum plane between the upper Middle Ordovician of Great Britain and North America that can be closely correlated. As has been previously stated, the slight difference between the American species *H. (Brongniartella) trentonensis* and the British species, *H. (Brongniartella) bisulcatus* indicates that the former is probably a migrant derived from this British species. If

this is the case, it must be stratigraphically younger than the first specimens of *bisulcatus*, and might be younger than the later specimens, depending on when the migration started. It could even be contemporaneous with the later specimens of *H. (Brongniartella) bisulcatus*. As *H. (Brongniartella) trentonensis* is only found in thirty-three stratigraphic feet of rock in the Pennsylvania section, it would seem that it had migrated from Great Britain, established itself, and lived on until adverse conditions killed it off, but that no more migrations were made from the parent stock to strengthen the new colony.

#### British Correlations Summarized

From the above statements of stratigraphic range the following conclusions are drawn regarding the correlation between Shropshire and central Pennsylvania:

I. The brachiopods, *Parastrophia hemiplicata* and *Triplecia* sp., do not give any helpful information, as they do not occur in the Shropshire section.

II. The graptolite zone of *Dicranograptus clingani*, with which the Salona graptolite beds are correlated, includes the upper part of the Soudleyan and Lower Longvillian, and may contain much higher beds.

III. *Cryptolithus tessalatus* is a derivation from a form which migrated from the central stock in pre-Soudleyan time; but it did not arrive in America until Salona time, and it may be of the same age as British species with the two exterior row type of brim.

IV. *Homalonotus (Brongniartella) trentonensis* is derived from *H. (Brongniartella) bisulcatus*, and must be younger than the oldest occurrence of *H. (Brongniartella) bisulcatus*, but can be contemporaneous with, or younger than the later specimens of this species.

V. *Cryptolithus tessalatus* and *Homalonotus (Brongniartella) trentonensis* are derivatives of British forms, and migrated at different rates of speed. The ancestors of *C. tessalatus* must have left the parent stock in pre-Soudleyan time, whereas those of *H. (Brongniartella) trentonensis* could not have left until early Upper Longvillian time. In spite of this difference in the time of departure, both species are found to appear first in the Salona formation at approximately the same time, indicating a different rate of migration. The Salona formation can, therefore, upon the evidence of *H. (Brongniartella) trentonensis*, be no older than Upper Longvillian, and may be Marshbrookian, or even younger. As the upper limit of the *Dicranograptus clingani* zone is not definitely known, it may well include these younger beds.

It is therefore believed that the Salona formation may be fairly closely correlated with beds of Upper Longvillian or Marshbrookian age in England, and that the trilobites of the genus *Homalonotus (Brongniartella)* give the best and most accurate fossil evidence for this correlation. Other fossils serve as confirmatory checks, but the correlation based on these alone could not be made as closely without this one genus of trilobites.